

cent of their research equipment funds from the Federal Government; in contrast, Federal support accounted for more than two-thirds of equipment funding in the physical sciences, computer sciences, and environmental sciences. (See appendix table 5-21.)

The share of research equipment expenditures funded by the Federal Government declined from 62 to 58 percent between 1983 and 1999, although not steadily. This overall pattern masks different trends in individual S&E fields. For example, the share funded by the Federal Government actually rose during this period for both the social and the environmental sciences.

R&D Equipment Intensity. R&D equipment intensity is the percentage of total annual R&D expenditures from current funds devoted to research equipment. This proportion was lower in 1999 (5 percent) than it was in 1983 (6 percent), although it peaked in 1986 (7 percent). (See appendix table 5-22.) R&D equipment intensity varies across S&E fields. It tends to be higher in physical sciences (about 10 percent in 1999) and lower in social sciences (1 percent) and psychology (2 percent). For the two latter fields, these differences may reflect the use of less equipment, less expensive equipment, or both.

Doctoral Scientists and Engineers in Academia

U.S. universities and colleges are central to the nation's scientific and technological prowess. They generate new knowledge and ideas that form the basis of innovation that is vital to the advancement of science. In the process, they produce the highly trained talent needed to exploit and refresh this new knowledge. In addition, academia increasingly plays an active part in the generation and exploitation of new products, technologies, and processes.

The confluence of these key functions: the pursuit of new knowledge, the training of the people in whom it is embodied, and its exploitation toward generating innovation, makes academia a national resource whose vitality rests in the scientists and engineers who work there. Especially important are those with doctoral degrees who do the research, teach and train the students, and stimulate or help to produce innovation. Who are they, how are they distributed, what do they do, how are they supported, and what do they produce?¹⁸

Employment and research activity at the 125 largest research-performing universities in the United States are a special focus of analysis.¹⁹ These institutions have a disproportionate influence on the nation's academic science, engineering, and R&D enterprise. They enroll 22 percent of

full-time undergraduates and award one-third of all bachelors' degrees, but 40 percent of those in S&E; their baccalaureates, in turn, are the source of 54 percent of the nation's S&E doctoral degree-holders and more than 60 percent of those in academia with R&D as their primary work function. Their influence on academic R&D is even larger: they conduct more than 80 percent of it (as measured by expenditures), and they produce the bulk of academic article outputs and academic patents. For these reasons, they merit special attention.

Growth in academic employment over the past half century reflected both the need for teachers, driven by increasing enrollments, and an expanding research function, largely supported by Federal funds. Trends in indicators relating to research funding have been presented above, this section presents indicators about academic personnel. Because of the intertwined nature of academic teaching and research, much of the discussion deals with the overall academic employment of doctoral-level scientists and engineers, specifically the relative balance between faculty and nonfaculty positions, demographic composition, faculty age structure, hiring of new Ph.D.s, trends in work activities, and trends in Federal support. The section also includes a discussion of different estimates of the nation's academic R&D workforce and effort and considers whether a shift away from basic research toward more applied R&D functions has occurred.

Academic Employment of Doctoral Scientists and Engineers

Universities and colleges employ less than half of doctoral scientists and engineers.²⁰ Academic employment of S&E doctorate holders reached a record high of 240,200 in 1999, approximately twice their number in 1973. Long-term growth of these positions was markedly slower than that in business, government, and other segments of the economy. The academic doubling compares with increases of 230 percent for private companies, 170 percent for government, and 190 percent for all other segments. As a result, the academic employment share dropped from 55 to 45 percent during the 1973–99 period.

Within academia, growth was slowest for the major research universities. Text table 5-5 shows average annual growth rates for S&E Ph.D.-holders in various segments of the U.S. economy; appendix table 5-23 breaks down academic employment by type of institution.

Foreign-Born Academic Scientists and Engineers

An increasing number (nearly 30 percent) of Ph.D.-level scientists and engineers at U.S. universities and colleges are foreign-born. Like other sectors of the economy, academia has long relied extensively on foreign talent among its faculty, students, and other professional employees; this reliance increased during the 1990s. By a conservative estimate, for-

¹⁸The academic doctoral S&E workforce includes full and associate professors (referred to as "senior faculty"); assistant professors and instructors (referred to as "junior faculty"); and lecturers, adjunct faculty, research and teaching associates, administrators, and postdoctorates. S&E fields are defined by field of Ph.D. degree. All numbers are estimates rounded to the nearest 100. The reader is cautioned that small estimates may be unreliable.

¹⁹This set of institutions comprises the Carnegie Research I and II universities, based on the following 1994 classification: institutions with a full range of baccalaureate programs, commitment to graduate education through the doctorate, annual award of at least 50 doctoral degrees, and receipt of Federal support of at least \$15.5 million (1989–91 average); see Carnegie Foundation for the Advancement of Teaching (1994). The classification has since been modified, but the older schema is more appropriate to the discussion presented here.

²⁰ Unless specifically noted, data on doctoral scientists and engineers refer to persons with doctorates from U.S. institutions, surveyed biannually by NSF in the *Survey of Doctorate Recipients*.

Text table 5-5.

Average growth rates for employment of doctoral scientists and engineers in the U.S. economy (Percent)

Sector	1973–81	1981–91	1991–99
All sectors	5.7	3.4	2.3
Academia, total	4.4	2.8	1.7
Research universities ...	4.3	2.6	0.6
All others	4.7	3.0	2.7
Business	8.2	2.2	4.4
Government	5.0	2.3	4.9
All others	6.7	8.6	–3.4

SOURCE: National Science Foundation, Division of Science Resources Studies (NSF/SRS), Survey of Doctorate Recipients.

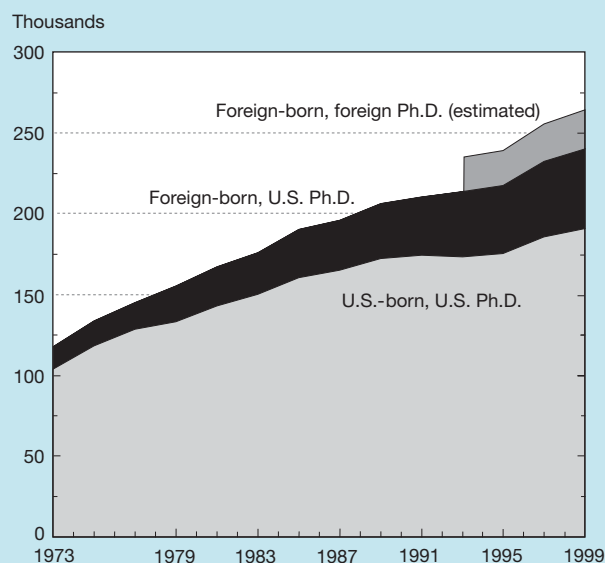
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eign-born Ph.D.-holders accounted for about 28 percent of the total number of academically employed doctoral scientists and engineers at the end of the decade. Figure 5-18 delineates the academic employment estimate of 240,200 U.S.-earned Ph.D.s into those awarded to U.S. citizens and those awarded to foreign-born individuals.

The figure also shows an estimate of 24,300 individuals with S&E doctorates from foreign universities for each of the survey years.²¹ The number is derived from the relationship of foreign-earned degrees to all U.S.-earned Ph.D.s in 1993, which was based on a sample drawn from the full doctoral population in the United States at the time of the 1990 census. (See text table 5-6.) The estimate of 24,300 represents a lower-bound value. It fails to take into account the rising pace of immigration into the United States during the 1990s, the creation of

²¹The actual 1999 survey estimate of 17,400 is clearly an underestimate. It is based only on a sample of those who were in the country in 1990 and responded to a 1999 survey of doctorate degree-holders.

Figure 5-18.

Academic employment of U.S.-born and foreign-born doctoral scientists and engineers: 1973–99

NOTE: Data on foreign-born foreign-earned Ph.D.s unavailable for 1973–91.

See appendix table 5-24 and text table 5-6.

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special visa programs to provide increased access to U.S. employment, an increase in the propensity of foreign Ph.D.-holders to remain in the United States, and some contrary evidence of a possible rise in return flows of foreign nationals in the second half of the decade. No reliable quantitative data are available on which to base a more solid estimate of the effects of these developments on academic employment.

Text table 5-6.

Estimates of foreign-born Ph.D. scientists and engineers at U.S. universities and colleges

Source of doctorate and place of birth	1973	1983	1993	1995	1997	1999
Total Ph.D. scientists and engineers						
Estimate 1	NA	NA	235,347	237,716	250,680	257,598
Estimate 2	NA	NA	235,347	239,513	255,987	264,427
Ph.D.s earned in U.S. (total)	117,957	176,082	213,758	217,543	232,505	240,169
Born in U.S.	104,426	150,397	173,288	175,764	185,957	191,158
Foreign-born	13,531	25,685	40,470	41,779	46,548	49,011
Ph.D.s earned abroad (total)						
Estimate 1	NA	NA	21,589	20,174	18,175	17,428
Estimate 2	NA	NA	21,589	21,971	23,482	24,257
Percent foreign-born						
Estimate 1	NA	NA	26.4	26.1	25.8	25.8
Estimate 2	NA	NA	26.4	26.6	27.4	27.7

NA = not available

NOTE: Estimate 1 is derived from Scientists and Engineers Statistical Data System (SESTAT). Estimate 2 is derived by applying the 1993 ratio of non-U.S.- to U.S.-earned degrees from SESTAT to all years. Data for 1973, 1983, and 1993 U.S.-born includes all persons with unknown place of birth.

See appendix table 5-24.

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Nevertheless, figure 5-18 suggests that participation by foreign-born doctorate-holders in U.S. academic S&E increased continuously during at least the past two decades. For those with U.S.-earned doctoral degrees, employment rose from 11.7 percent in 1973 to 20.4 percent in 1999; for postdoctorates, it is double that percentage. (See appendix table 5-24.) Adding the lower-bound estimate for those with foreign-earned degrees boosts these percentages from 26.4 percent in 1993 to 27.7 percent in 1999.

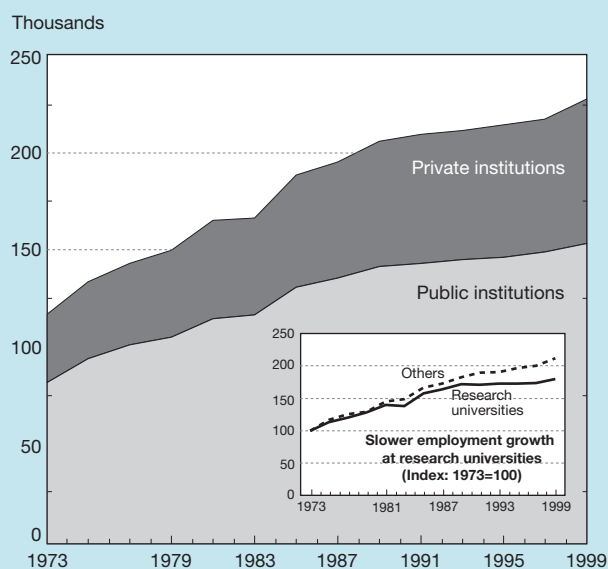
Slower Hiring at Research Universities and Public Institutions

Employment growth over the past decade was slower at the research universities than at other universities and colleges, after enjoying robust earlier increases.²² (See appendix table 5-25.) From 1993 to 1999, doctoral S&E employment at research universities expanded by 3.8 percent. In contrast, employment at other institutions grew uninterruptedly for at least three decades, increasing by 10.8 percent during the 1990s, primarily during the second half of the decade. Figure 5-19 shows some of these employment trends.

During the 1990s, employment increased less rapidly at public universities and colleges than at their private counterparts (2.1 versus 8.0 percent for research universities; 9.3 versus 13.8 percent for others). Moreover, the much stronger growth in public universities and colleges outside the ranks

²²Unless specifically stated, all subsequent analyses are based on U.S. doctorates only, since there is insufficient information on the faculty status of foreign-degreed Ph.D.-holders and on which academic institutions employ them.

Figure 5-19.
Doctoral scientists and engineers employed
in public and private universities and colleges:
1973–99



See appendix table 5-25.

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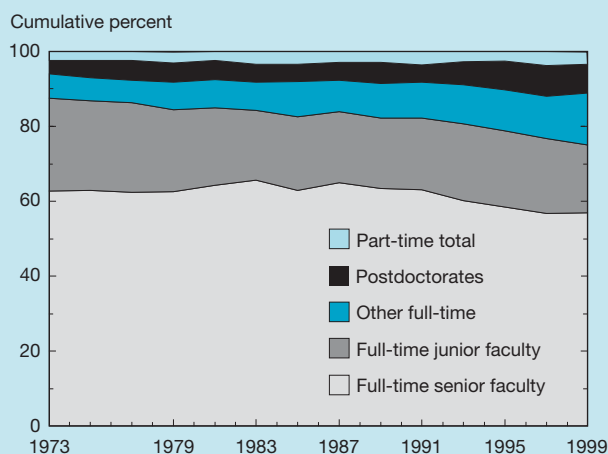
of the research universities suggests that state governments are more interested in expanding the institutional segment that focuses on education and training than in raising the employment of the flagship institutions that conduct most of the research. (See appendix table 5-25.)

Declining Faculty Appointments, More Postdoctorate and Other Positions

The full-time tenured faculty position is being undermined as the academic norm by trends that accelerated in the 1990s. As faculty appointments decreased, appointments to postdoctorate and other types of positions increased. Overall, academic employment of doctoral scientists and engineers was quite robust, growing from 118,000 in 1973 to 240,200 in 1999. (See appendix table 5-26.) However, traditional faculty positions grew less rapidly, especially during the 1990s, when the number of senior faculty—full and associate professors—rose only modestly, and the number of junior faculty remained static. During that decade, full-time nonfaculty positions grew by half, as did postdoctorate appointments.

Figure 5-20 shows the resulting distribution in the structure of academic employment. The share of full-time senior faculty fell from 65 percent of total employment in the mid-1980s to only 57 percent in 1999, with particularly steep drops during the 1990s. The share of junior faculty also declined, bringing the overall faculty share to 75 percent of total employment, a steep loss from 88 percent in the early 1970s. The decline in the 1990s was linear, from 82 to 75 percent in fewer than 10 years. These employment trends in the past decade occurred as real academic R&D spending rose by half, retirement of faculty who had been hired during the expansionist 1960s increased, academic hiring of young Ph.D.-hold-

Figure 5-20.
Distribution of Ph.D. scientists and engineers,
by type of academic appointment: 1973–99



NOTE: Junior faculty includes assistant professors and instructors; senior faculty includes full and associate professors.

See appendix table 5-25.

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ers showed a modest rebound, and universities placed a growing emphasis on the practical application of academic research results, discussed later in this chapter.²³

Nonfaculty ranks, that is, full- and part-time adjunct faculty, lecturers, research and teaching associates, administrators, and postdoctorates, increased from 36,900 in 1989 to 59,800 in 1999. This 62 percent increase stood in sharp contrast to the 6 percent rise in the number of full-time faculty. Both the full-time nonfaculty and postdoctorate components both grew very rapidly between 1989 and 1999 (72 and 61 percent, respectively), while part-time employment rose 32 percent.²⁴ In fact, part-time employees accounted for between 2 and 4 percent of the total throughout the period. (See appendix table 5-26.)

Academic Employment Patterns for Recent Ph.D.-Holders

The trends just discussed reflect the pool of the entire academic workforce of S&E Ph.D.-holders. A sharper indication of current trends can be gleaned by looking at the academic employment patterns of those with recently awarded Ph.D.s, here defined as persons who earned their doctorates at U.S. universities within three years of the survey year.

Recent Ph.D.-holders who enter academic employment today are more likely to receive postdoctorate appointments than faculty positions, which declined sharply over the past decade and have even undergone a reversal when viewed over the longer term. Those in research universities are more than twice as likely to be in postdoctorate appointments as to have faculty rank. (See appendix table 5-27 and figure 5-21.) Overall, since 1973, the percentage of recent Ph.D.-holders hired into full-time faculty positions has been cut nearly in half, from 74 to 37 percent. The decline at research universities has been sharper, from 60 to 24 percent. Conversely, the overall proportion of Ph.D.-holders who reported being in postdoctorate positions has risen from 13 to 43 percent (and from 21 to 58 percent at research universities). Those in public research institutions are somewhat more likely than those in private institutions to hold full-time faculty positions and somewhat less likely to have postdoctorate rank.

Similar Trends for Young Ph.D.s With a Track Record

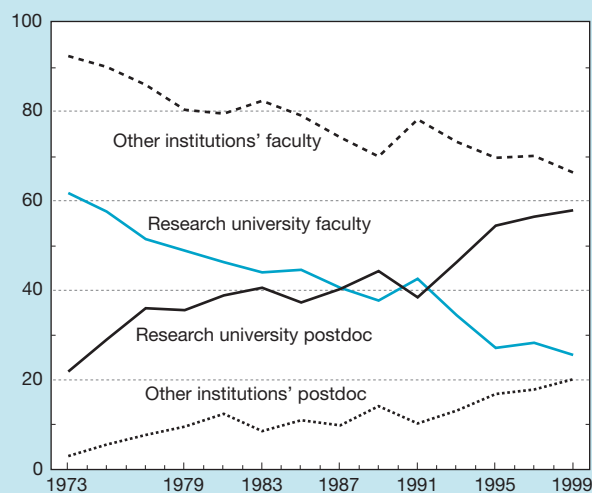
For those in academia four to seven years after earning their doctorates, the picture looks quite similar: only two-thirds had attained faculty rank at that point compared with nearly 90 percent in the early 1970s, and the trend continues to point downward. (See appendix table 5-27.) Only about half were in tenure-track positions, with 10 percent already tenured, well below the experience of previous decades. Moreover, the overall proportion of those in a tenure track position, whether al-

²³ It is impossible with the data at hand to establish causal connections among these developments.

²⁴ For more information on this subject, see "Postdoctorate Appointments" in chapter 3.

Figure 5-21.
Recent S&E Ph.D.s hired into faculty and postdoc positions at research universities and other academic institutions: 1973–99

Percent of institutions' recent Ph.D.s



NOTES: Recent Ph.D.s have earned doctorates within three years of the survey year. Those hired into other positions not shown.

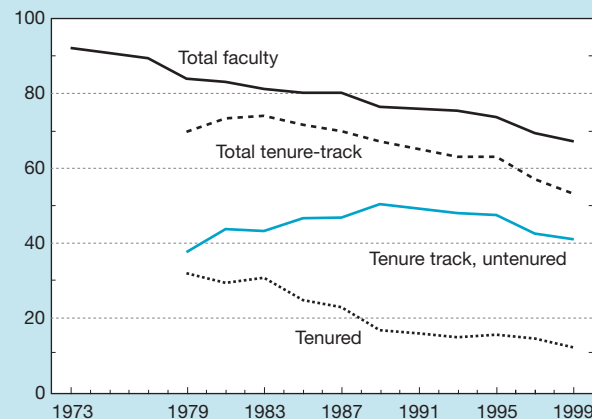
See appendix table 5-27. Science & Engineering Indicators – 2002

ready tenured or not, has declined for the past two decades, and this trend shows no sign of abating.

Taken together, these data suggest a continuing shift, accelerating during the 1990s, toward forms of employment outside traditional tenure track positions. (See figure 5-22.) This shift toward nonfaculty employment touched most major fields. In fact, gains in the total number of full-time fac-

Figure 5-22.
Faculty and tenure track-status of academic S&E Ph.D.s whose doctorate was earned 5–7 years earlier: 1973–99

Percent



SOURCE: National Science Foundation, Division of Science Resources Statistics. Survey of Doctorate Recipients.

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ulty positions were restricted to the life and computer sciences, with the other fields holding steady or registering only marginal increases. However, for every field except environmental (i.e., earth, atmospheric, and ocean) sciences, the proportion of total doctoral employment held by full-time faculty decreased. (See appendix table 5-26.)

Concerns About Retirement Behavior of Doctoral Scientists and Engineers

The trend toward fewer faculty appointments and more full-time nonfaculty and postdoctorate components is especially noteworthy because academia is in a period of increasing retirements. In the 1960s, the number of institutions, students, and faculty in the United States expanded rapidly, bringing many young Ph.D.-holders into academic faculty positions. This growth boom slowed sharply in the 1970s, and faculty hiring has since continued at a more modest pace. The result is that increasing numbers of faculty (and others in nonfaculty positions) are today reaching or nearing retirement age.²⁵

A law defining age discrimination, the Age Discrimination in Employment Act, became fully applicable to universities and colleges in 1994.²⁶ It prohibits the forced retirement of faculty at any age, raising concerns about the potential ramifications of an aging professorate for scholarly productivity and the universities' organizational vitality, institutional flexibility, and financial health. These concerns were the focus of a National Research Council (NRC) (1991) study. The study concluded that "overall, only a small number of the nation's tenured faculty will continue working in their current positions past age 70" (NRC 1991, p. 29), but added: "At some research universities a high proportion of faculty would choose to remain employed past age 70 if allowed to do so" (NRC 1991, p. 38).

Sufficient data have now accumulated to allow examination of these concerns. Figure 5-23 shows the age distribution of academic doctoral scientists and engineers, and figure 5-24 displays the percentage of academic doctoral scientists and engineers 60 years of age or older. They show that the proportion of 60- to 64-year-olds was rising well before the act became mandatory, then leveled off. A similar progression can be seen for those age 65 or older, who made up 3 percent of the research universities' full-time faculty and 2 percent of other institutions' full-time faculty in 1999. The employment share of those older than age 70 rose during the last quarter century; it stood at 0.5 percent in 1999. (See appendix tables 5-28 and 5-29.)

These data suggest that concerns that universities would continue to employ many unproductive professors have been

²⁵See also the discussion of retirements from the S&E workforce in chapter 3, "Science and Engineering Workforce."

²⁶A 1986 amendment to the Age Discrimination in Employment Act of 1967 prohibited mandatory retirement on the basis of age for almost all workers. Higher education institutions were granted an exemption through 1993, allowing termination of employees with unlimited tenure who had reached age 70.

Figure 5-23.
Age distribution of full-time academic doctoral S&E faculty: 1973–99

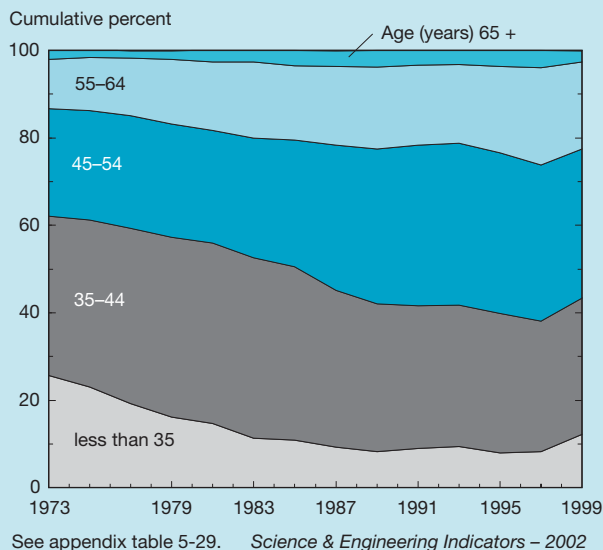
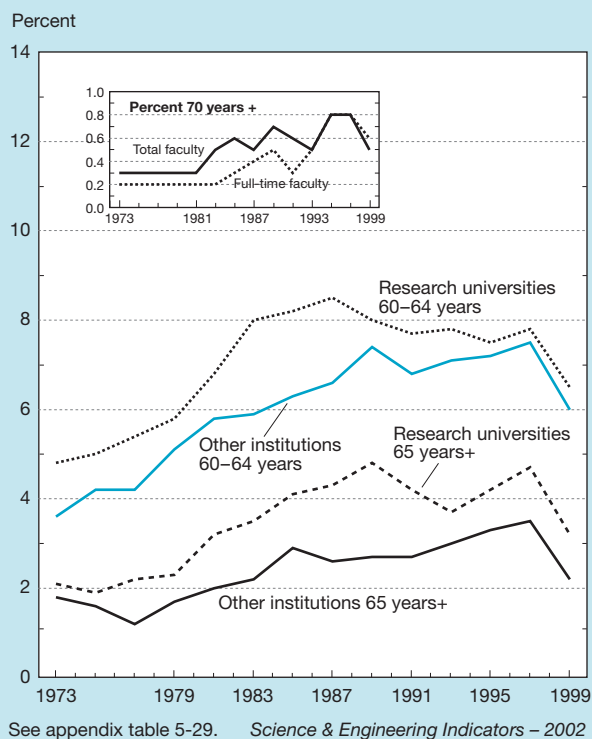


Figure 5-24.
Full-time faculty age 60 and older at research universities and other higher education institutions: 1973–99



Text table 5-7.

Percentage of academic S&E doctorate holders leaving full-time employment in 1993–95 period, by number of articles published in previous five years

Age in 1995	Number of articles			
	Total	0	1–5	6 or more
51–55	3.2	5.7	3.5	1.0
56–60	9.2	12.2	8.6	6.7
61–65	24.6	32.6	23.5	16.1
66–70	35.7	—	43.1	28.0
71–73	40.6	—	—	28.1

— = number of cases too small to estimate

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

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misplaced. Further evidence is provided by examining the article output of those retiring at different ages, as shown in text table 5-7. The table compares the 1993–95 transition rates from full-time academic employment of S&E Ph.D.-holders with the number of articles they reported publishing over the previous five years. Within each age group, those with six or more articles were less likely to leave full-time employment than those with fewer or no articles.

Women and Minority Group Members As Faculty Role Models

The relatively large annual supply of new S&E doctorate-holders suggests that finding a sufficient number of replacement faculty may not be difficult. However, accumulating research points to the importance of role models and mentoring to student success in mathematics, science, and engineering, especially for women and minorities. These two groups make up a pool of potential scientists and engineers that has not been fully tapped and that, in the case of minorities, represents a growing share of U.S. youth, estimated to reach 45 percent of the college-age population by 2025. (See appendix table 2-2.) Thus, the presence of women and minority faculty on college campuses may well be one important factor in the recruitment of women and minorities to these fields. What have been the major hiring trends for them, and what is their current status?

Women

The academic employment of women with S&E doctorates has risen steeply over the past quarter century, reflecting the steady increase in the proportion of women among holders of newly awarded S&E doctorates. The number of women in academia increased sixfold between 1973 (when this type of employment information was first collected) and 1999, from 10,700 to an estimated 64,400, bringing their share from 9 to 27 percent. (See appendix table 5-30.) By the end of the decade, women constituted just under one-quarter of full-time

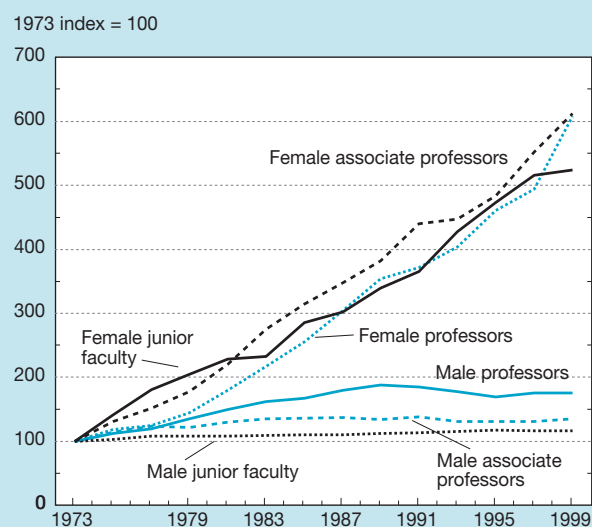
faculty, up from 6 percent. Compared with men, women faculty remain relatively more heavily concentrated in life sciences and psychology, with correspondingly lower shares in engineering, physical sciences, and mathematics.

Women's growing share of academic employment reflects the confluence of three factors: their rising proportion among new doctorates, somewhat greater predilection for choosing an academic career, and being hired into these positions at somewhat higher rates than men. This historical dynamic is reflected in declining numbers of women as one moves up in faculty rank: in 1999, women constituted 12 percent of full professors, 25 percent of associate professors, and 37 percent of the junior faculty, the latter roughly in line with their recent share of Ph.D.s earned. (See the section "Doctoral Degrees by Sex" in chapter 2.) In contrast, the number of men increases as one moves from junior to senior faculty ranks. (See figure 5-25.) This contrasting pattern indicates the recent arrival of significant numbers of women doctorate-holders in full-time academic faculty positions. It suggests that the number of women among the faculty will continue to increase, assuming that women stay in academic positions at a rate equal to or greater than men.

Underrepresented Minorities

The U.S. Census Bureau's demographic projections have long indicated an increasing prominence of minority groups among future college and working-age populations. With the exception of Asians/Pacific Islanders, these groups have tended to be less likely than the majority population to earn S&E degrees or work in S&E occupations. Private and gov-

Figure 5-25.
Growth in full-time doctoral S&E faculty, by rank and sex: 1973–99



NOTE: Junior faculty includes assistant professors and instructors.

SOURCE: National Science Foundation, Division of Science Resources Statistics. Survey of Doctorate Recipients.

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ernmental groups have sought to broaden the participation of blacks, Hispanics, and American Indians/Alaskan Natives in these financially attractive fields, with many programs targeting their advanced training through the doctorate.

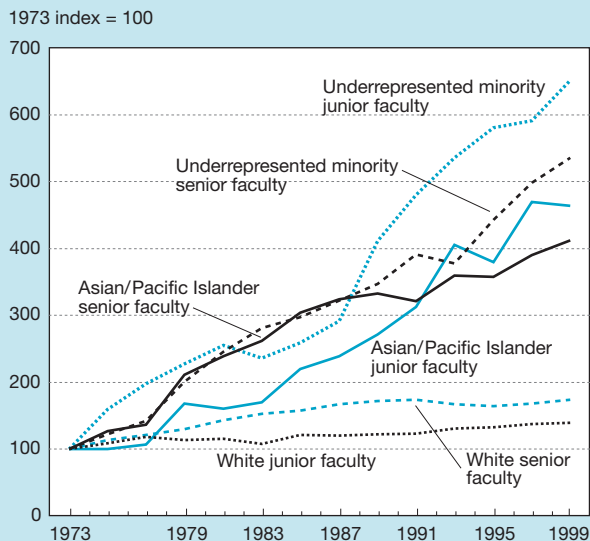
In response, the rate of increase in conferrals of Ph.D.s to members of minority groups has been steep,²⁷ as have increases in academic employment; but taken together, blacks, Hispanics, and American Indians/Alaskan Natives remain a small minority. (See figure 5-26 and appendix table 5-31.) Because the increases in hiring come from a very small base, these groups still constitute less than 7 percent of total employment but represent nearly 10 percent of recent Ph.D.-holders hired into academia. Their share of full-time faculty positions is very similar to their employment share. Compared with whites, blacks tend to be relatively concentrated in the social sciences and psychology and relatively less so in the physical, environmental (earth, atmospheric, and ocean), and life sciences. The field distribution of Hispanic degree-holders is similar to that of the majority.

Asians/Pacific Islanders

Asians/Pacific Islanders as a group have been quite successful in entering the academic doctoral workforce in S&E, sending their employment share from 4 to 11 percent since 1973. Compared with whites, they are more heavily repre-

²⁷This, in turn, reflects their rising participation in higher education and graduate school training. See “Master’s Degrees by Sex, Race/Ethnicity, and Citizenship” and “Doctoral Degrees by Race/Ethnicity” in chapter 2.

Figure 5-26.
Growth in full-time doctoral S&E faculty,
by rank and race/ethnicity: 1973–99



NOTES: Underrepresented minority faculty includes blacks, Hispanics, and American Indians/Alaskan Natives. Junior faculty includes assistant professors and instructors; senior faculty includes full and associate professors.

See appendix table 5-31. *Science & Engineering Indicators – 2002*

sented in engineering; represented to lesser degrees in life and physical sciences, mathematics, and computer science; and represented at very low levels in psychology and social sciences. In 1999, Asians/Pacific Islanders constituted nearly one-quarter of academic doctoral computer scientists and 18 percent of engineers. (See appendix table 5-31.)

In the last half of the 1990s, the percentage of Asian Ph.D.s among recent doctorate-holders sharply reversed a steep two-decade climb. The decline reflects a sharp drop in the percentage of all S&E doctoral degrees earned by Asians in the closing years of the 1990s. Between 1995 and 1999, S&E doctoral degrees awarded in the United States fell by 2 percent, but those awarded to Asians dropped by 45 percent. Consequently, the share decline of Asians among recent doctorate-holders is also evident in industry and other employment sectors.

Size of the Academic Research Workforce

The intertwined nature of research, teaching, and public service in academia makes it difficult to define the size of the academic research workforce precisely. Therefore, two estimates of the number of academic researchers are presented: a headcount of those who report that research is their primary work activity, and a headcount of those who report that research is either their primary or secondary work activity.

Postdocs and those in nonfaculty positions are included in both estimates. To provide a more complete measure of the number of researchers, a lower-bound estimate of the number of graduate students who support the academic research enterprise is included, based on those with research assistantship (RA) support.

Research as Primary Work Activity

By this measure, the growth of doctoral-level academic researchers has been substantial, from 27,800 in 1973 to 91,400 in 1999. (See appendix table 5-32.) During this period, the number of those with teaching as their primary activity increased much less rapidly, from 73,300 to 108,600. Figure 5-27 displays the resulting shifting proportions in the academic workforce. It shows that after many years of increase, the proportion of those reporting research as their primary activity leveled off in the 1990s, as did the steep drop in those reporting teaching as their primary activity.

The different fields have distinct patterns of relative emphasis on research, but the shapes of their overall trends are largely the same. Life sciences, however, stand out for their much higher proportion of those identifying research as their primary activity and, correspondingly, their much lower proportion of those reporting teaching as their primary activity. (See figure 5-28.)

Research as Either Primary or Secondary Work Activity

This measure, a straightforward headcount of doctoral respondents for whom research is either the primary or secondary work activity, also shows greater growth in the research than in the

Figure 5-27.
Primary work activity of academic doctoral S&E faculty: 1973–99

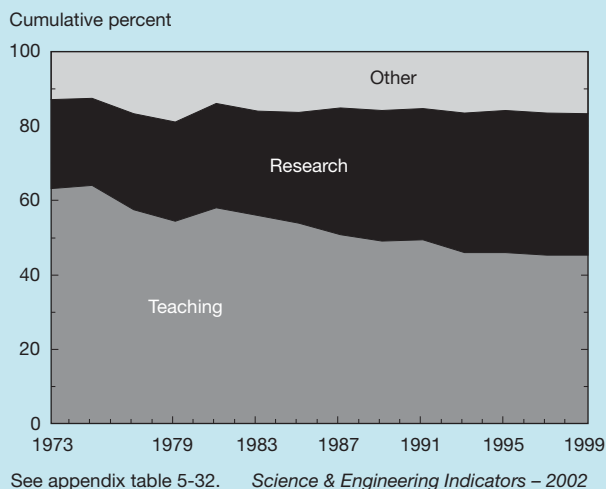
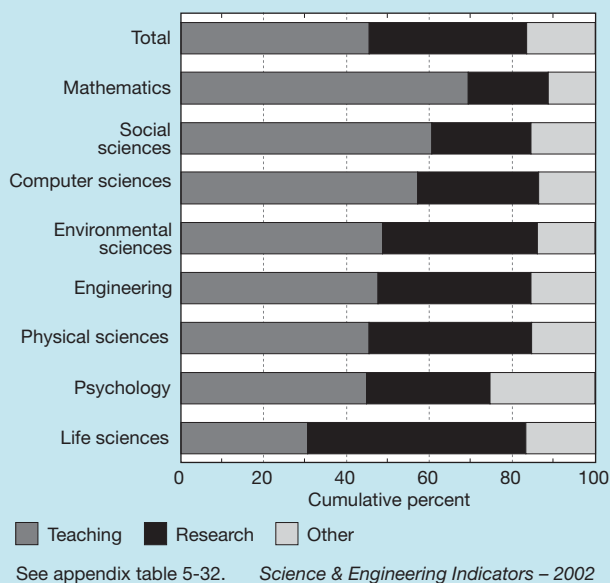


Figure 5-28.
Primary work activity of academic doctoral S&E workforce: 1999



teaching component. The number of doctoral researchers so defined increased from 82,300 in 1973 to 168,100 in 1999, that of teachers from 94,900 to 158,700.²⁸ (See appendix table 5-33.)

Life sciences accounted for much of this trend, with researchers growing from 26,000 to 60,800 and teachers from about the same base of 25,300 to 43,600. The other fields generally included fewer researchers than teachers in the early

²⁸This measure was constructed slightly differently in the 1980s and in the 1990s, starting in 1993, and is not strictly comparable across these periods. Therefore, the crossing over of the two trends in the 1990s could reflect only a methodological difference. However, the very robust trend in the life sciences, where researchers started outnumbering teachers at a much earlier time, suggests that this methodological artifact cannot fully explain the observed trend.

1970s, but this trend has been reversed for physical, earth, atmospheric, and ocean sciences and engineering.

The close coupling of advanced training with hands-on research experience is a key strength of American graduate education. To the headcount of doctoral researchers for whom research is a primary or secondary work activity must thus be added an estimate of the number of graduate students who are active in research. The more than 300,000 full-time S&E graduate students can be expected to contribute significantly to the conduct of academic research.

Graduate RAs were the primary means of support for slightly more than one-quarter of these students. Text table 5-8, which shows the distribution of all full-time graduate students and graduate research assistants by field over the past quarter century, indicates that the number of research assistants has grown faster than overall graduate enrollment. In both enrollment and distribution of RAs, a shift away from physical sciences and into life sciences has occurred. Nevertheless, engineering, natural sciences, and mathematics and computer sciences have relatively higher proportions of research assistants measured against their enrollment.²⁹ For life sciences, enrollment and research assistant proportions are in balance, reflecting the relatively heavier reliance of these fields on postdoctoral researchers.

In estimating the headcount of doctoral researchers for whom research is the primary or secondary activity, only graduate research assistants (full-time graduate students whose primary mechanism of support is an RA) are included. Thus, the estimate excludes graduate students who rely on fellowships, traineeships, or teaching assistantships for their support, as well as the nearly 40 percent who are primarily self-supporting; and foreign-degreed doctoral researchers. With these caveats, the number of academic researchers in 1999 for whom research is the primary or secondary activity is estimated to have been close to 260,000. (See figure 5-29 and appendix table 5-34.) It is worth noting that in computer science and engineering the number of graduate research assistants exceeded the number of doctoral researchers.

Deployment of the Academic Research Workforce

This section describes trends in researcher headcount and in the number of S&E academicians whose primary activity is research. They are discussed as measures of the relative research intensity of academic institutions and the distribution of the academic research workforce across types of institutions, positions, and fields. The analysis is based on doctoral scientists and engineers with degrees from U.S. institutions, because insufficient detail is available for those with foreign degrees.

Distribution Across Types of Academic Institutions

The majority of the research workforce is concentrated in the research universities, followed by comprehensive and doctorate-granting institutions and freestanding medical institutions. (See appendix table 5-35.) In 1999, the research

²⁹ This reflects increasing support for computer science R&D.

Text table 5-8.

Full-time S&E graduate students and graduate research assistants at U.S. universities and colleges, by field

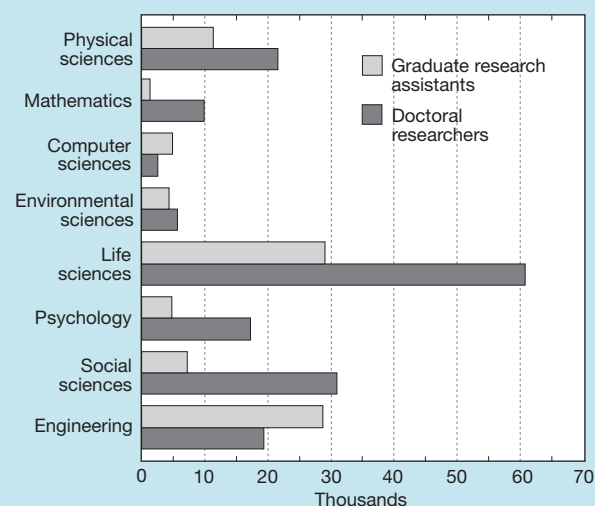
Year	Total S&E	Engineering	Physical sciences	Environmental sciences ^a	Mathematics and computer sciences	Life sciences	Psychology	Social sciences
Full-time graduate students (thousands)								
1973	161.6	31.2	21.1	7.8	13.3	40.7	15.2	32.4
1983	252.1	53.9	25.2	12.0	21.6	69.3	26.6	43.5
1993	329.7	73.8	30.6	11.4	31.9	91.7	34.8	55.6
1999	334.4	67.8	26.6	10.5	34.5	107.0	34.7	53.3
Full-time graduate research assistants (thousands)								
1973	35.9	10.4	6.3	2.6	1.4	9.5	1.9	4.0
1983	54.9	15.5	9.1	3.5	2.2	16.5	3.0	5.0
1993	90.2	27.9	12.3	4.7	5.2	28.0	4.6	7.4
1999	91.3	28.7	11.3	4.3	6.2	29.0	4.8	7.2
Distribution of full-time graduate students (percent)								
1973	100	19	13	5	8	25	9	20
1983	100	21	10	5	9	27	11	17
1993	100	22	9	3	10	28	11	17
1999	100	20	8	3	10	32	10	16
Distribution of full-time graduate research assistants (percent)								
1973	100	29	18	7	4	26	5	11
1983	100	28	17	6	4	30	5	9
1993	100	31	14	5	6	31	5	8
1999	100	31	12	5	7	32	5	8

^aEnvironmental sciences include earth, atmospheric, and ocean sciences.

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Graduate Students and Postdoctorates.

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Figure 5-29.

Estimated number of doctoral academic researchers and graduate research assistants, by field: 1999

NOTE: Academic researchers include those whose primary or secondary work activity is basic or applied research, development, or design.

See appendix table 5-34. *Science & Engineering Indicators – 2002*

universities employed 54 percent of doctoral scientists and engineers in academic positions, 61 percent of academic researchers (headcount), 76 percent of those whose primary activity is research, and 80 percent of graduate research assistants. The employment shares of the other institutions are generally the same or higher than their share of the researcher measures.

Over the years, the research universities' share of academic researchers has declined, reflecting their decreasing shares of total and Federal academic research expenditures. The research universities' losses were offset by gains in several other types of institutions. Text table 5-9 provides a long-term overview of the changes in these institutional distributions. (See appendix table 5-35.)

Distribution Across Academic Positions

A pool of academic researchers outside the regular faculty ranks has grown over the years, as shown by the distribution of the doctoral research workforce across different types of academic positions: faculty, postdoctoral fellows, and all other types of appointments. (See text table 5-10 and appendix table 5-36.) The faculty share of the academic research workforce (77 percent in 1999, approximately the same as their employment share) represents a decline from 89 percent in 1973. The shift toward nonfaculty research effort was

Text table 5-9.

Distribution of academic doctoral employment and researchers, by institution type
(Percentage)

Type of institution	Employment		Researchers		Graduate Research Assistants	
	1970s	1990s	1970s	1990s	1970s	1990s
Total	100.0	100.0	100.0	100.0	100.0	100.0
Research universities	57.3	54.6	66.7	61.4	87.8	81.2
Doctorate-granting institutions	12.3	12.2	11.6	12.1	9.1	11.2
Comprehensive institutions	18.6	19.4	12.7	15.0	1.7	4.5
All others	11.8	13.8	9.0	11.5	1.2	3.1

NOTES: Researchers are headcounts of those with research as primary or secondary work activity. "All others" includes freestanding medical schools, schools of engineering, and four-year colleges.

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

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Text table 5-10.

Change in the composition of academic employment and academic researchers

Year	Total employment	Researcher headcount	Research is primary activity
Number (thousands)			
1973	118.0	82.3	27.8
1983	176.1	104.7	48.9
1993	213.8	150.1	80.2
1999	240.2	168.1	91.4
Full-time faculty (%)			
1973	87.6	87.5	71.3
1983	84.3	83.0	68.8
1993	80.7	81.1	70.9
1999	76.6	76.8	66.1
Postdoctorates (%)			
1973	3.5	4.9	13.8
1983	4.7	7.1	14.6
1993	6.2	8.9	15.8
1999	7.7	10.6	18.2
Other full- and part-time positions (%)			
1973	6.4	5.6	11.3
1983	9.2	8.6	14.4
1993	13.1	10.0	13.3
1999	15.6	12.5	15.7

NOTE: Researcher headcount is the sum of those for whom research is either the primary or secondary work activity.

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

See appendix table 5-36. *Science & Engineering Indicators – 2002*

especially pronounced in the 1990s. The data on share of employment and researcher headcount show increases for both postdoctorates and those in a variety of nonfaculty positions.

Distribution Across S&E Fields

The distributions of researchers and those whose primary activity is research were compared with the employment distribution. Researcher proportions in excess of a field's employment share were deemed to indicate greater research intensity. Text table 5-11 suggests that, by these measures, life sciences expend relatively more research effort than the other fields, and mathematics and social sciences expend relatively less. Life sciences have a smaller-than-expected share of graduate research assistants, reflecting their relatively heavy use of postdoctorates in research. (See appendix table 5-37.)

Research Intensity of Academic Institutions

Has the relative importance given to R&D in U.S. universities and colleges changed? In terms of inputs, this question has already been addressed by examining the number of dollars spent on R&D. See "Emphasis on Research at Universities and Colleges" earlier in this chapter. In this section, the question is addressed in terms of the number of academic research personnel using relative-to-total doctoral employment in S&E. The two measures, headcount and the number of those reporting research as their primary work activity, tell somewhat different stories. The reader is cautioned that the resulting ratios are suggestive rather than definitive.

The number of researchers (headcount) relative to total employment declined from its high in the 1970s to a low in the mid-1980s, then rose again to about the previous levels, indicating declining research intensity during the 1970s and early 1980s, when R&D funds grew relatively slowly. (See text table 5-12 and appendix tables 5-35 to 5-37.) The data also show that for computer sciences and earth, atmospheric, and ocean sciences, levels of research involvement were somewhat lower in the late 1990s than earlier in the decade. A long-term upward trend, from about 25 percent of total employment to nearly 40 percent, is evident in the percentage of those whose primary activity is research. This may indicate a strengthening of the research function in academia. (See figure 5-30.)

Text table 5-11.

Distribution of academic employment and researchers, by field: 1999
(Percent of academic total)

Field	Total employment	Researcher headcount	Research is primary activity	Graduate research assistants
Total	100.0	100.0	100.0	100.0
Physical sciences	12.9	12.8	13.3	12.3
Mathematics	6.3	5.9	3.2	1.4
Computer sciences	1.5	1.6	1.2	5.4
Earth, atmospheric, and space sciences	3.2	3.4	3.2	4.7
Life sciences	34.1	36.2	47.2	31.7
Psychology	12.1	10.2	9.5	5.3
Social sciences	19.2	18.4	12.1	7.9
Engineering	10.6	11.6	10.3	31.4

NOTES: Percentages may not add to 100 because of rounding. Researcher headcount is the sum of those for whom research is either the primary or secondary work activity.

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

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Text table 5-12.

Research intensity of American universities
(Ratio of researcher headcounts to employment)

Field	1973	1983	1993	1999
S&E total	0.70	0.59	0.70	0.70
Physical sciences	0.74	0.64	0.70	0.70
Mathematics	0.70	0.56	0.62	0.65
Computer sciences	NA	0.74	0.79	0.71
Earth, atmospheric, and ocean sciences	0.72	0.68	0.78	0.73
Life sciences	0.75	0.70	0.76	0.74
Psychology	0.60	0.50	0.60	0.59
Social sciences	0.61	0.46	0.66	0.67
Engineering	0.73	0.62	0.76	0.76

NA = not available

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

See appendix tables 5-35 to 5-37.

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Government Support of Academic Doctoral Researchers

Academic researchers rely on the Federal Government for a significant share of their overall research support because about 60 percent of all academic R&D is federally funded. The institutional and field distributions of these funds are well documented, but little is known about their distribution across researchers. This section presents data from reports by doctoral scientists and engineers about the presence or absence of Federal support and an indication from those so supported as to which agencies have provided them with funds. However, nothing is known about the magnitude of these funds to individual researchers. (See sidebar, “Interpreting the Federal Support Data.”)

Appendix table 5-38 shows the percentage of academic doctoral scientists and engineers who have received Federal support for their work, broken out by field. The analysis ex-

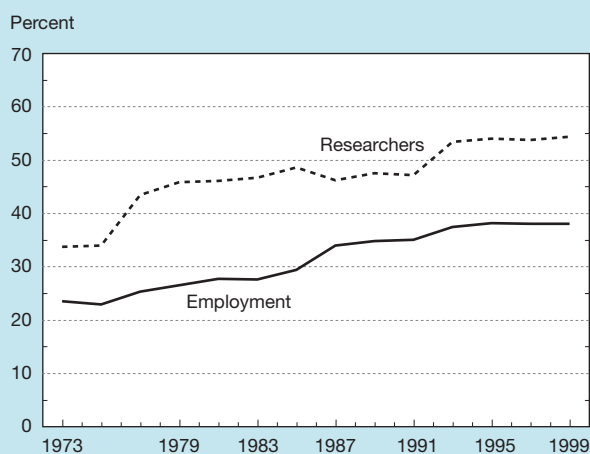
amines the overall pool of doctoral S&E researchers as well as young Ph.D.-holders, for whom support may be especially critical in establishing a productive research career.

Academic Scientists and Engineers With Federal Research Funds

In 1999, the Federal Government supported an estimated 46 percent of all doctoral academic scientists and engineers, 74 percent of those for whom research was the primary responsibility, and 37 percent of those for whom research was a secondary responsibility. (See appendix table 5-38.) With the exception of engineering, no major shifts appear to have occurred in the overall percentage of those so supported during the 1993–97 period. However, as text table 5-13 shows, the 1999 percentages, for S&E as a whole and physical sciences, mathematics, life sciences, psychology, and social sciences, were below those of the late 1980s, when Federal academic research funds were growing rapidly.

Figure 5-30.

S&E Ph.D.s employed in academe with research as primary activity as a percentage of all academic S&E Ph.D.s and of academic S&E Ph.D. researchers: 1973–99



NOTE: Academic researchers include those whose primary or secondary work activity is basic or applied research, development, or design.

See appendix tables 5-32 and 5-34.

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The percentage of researchers who receive Federal support differs greatly across the S&E fields. In 1999, Federal support of S&E researchers ranged from 63 percent in earth, atmospheric, and ocean sciences to 29 percent in mathematics and 23 percent in social sciences. The earlier series (1973–91) shows an overall decline in the proportion of federally supported researchers through the early 1980s that coincided with stagnant real Federal R&D funds to academia, followed by a rise in the proportion supported during the second half of the 1980s, when funding again rose robustly. (See appendix table 5-38.)

Full-time faculty received Federal funding less frequently than other full-time doctoral employees, who, in turn, were less frequently supported than postdoctorates. In 1999, 43 percent of full-time faculty, 50 percent of other full-time employees, and 80 percent of postdoctorates received Federal support.

Interpreting Federal Support Data

Interpretation of the data on Federal support of academic researchers faces a technical difficulty. Between 1993 and 1997, respondents to the *Survey of Doctorate Recipients* were asked whether work performed during the week of April 15 was supported by the Federal Government; in most other survey years, the reference was to the entire preceding year; in 1985, it was to one month. However, as clearly illustrated by these data series, the volume of academic research activity is not uniform over the entire academic year. A one-week (or one-month) reference period seriously understates the number supported over an entire year. Thus, the 1993–97 numbers (and those for 1985) cannot be compared directly with results for the earlier years or those from the 1999 survey, which again used an entire reference year.

The discussion here compares 1999 data with the earlier series and examines trend information for the mid-1990s using the 1993–97 data points. All calculations express the proportion of those with Federal support relative to the number responding to this question. The reader is cautioned that, given the nature of these data, the trends discussed are broadly suggestive rather than definitive. The reader also is reminded that the trends in the proportion of all academic researchers supported by Federal funds occurred against a background of rising overall numbers of academic researchers.

Again, these proportions were lower than those during the latter part of the 1980s. (See appendix table 5-38.) It is unclear whether these estimates indicate relatively less generous support or greater availability of funds from other sources, some of which may not flow through university accounts.

Federal Support of Young Academic Ph.D.-Holders

Early receipt of Federal support is viewed as critical to launching a promising academic research career. The Federal

Text table 5-13.

Percentage of academic doctoral scientists and engineers with Federal support

Field	1979	1989	1999
S&E total	39.9	49.4	46.1
Physical sciences	44.1	58.2	55.7
Mathematics	21.7	33.5	29.1
Computer sciences	34.8	52.4	55.6
Earth, atmospheric, and ocean sciences	45.4	63.8	63.3
Life sciences	55.3	65.1	57.9
Psychology	32.6	35.5	32.9
Social sciences	20.4	27.7	22.9
Engineering	49.1	56.3	56.9

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

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Government supports young academic doctoral scientists and engineers at higher rates than it does the overall academic S&E workforce but supports those in full-time faculty positions, as opposed to postdocs and those in other full-time positions, at lower rates. (See appendix tables 5-38 and 5-39.) Overall, 53 percent of those with recently earned doctorates (within three years of the survey) received Federal research funds, but only 29 percent of those in full-time faculty positions did (sharply lower than the rate of nearly 40 percent in the late 1980s). On the other hand, 80 percent of the postdocs had Federal funds. Mathematics and psychology stood out as having low percentages of postdocs with Federal support (59 and 64 percent, respectively) compared with 77 to 82 percent for the other fields.

In 1999, after young academics had gained some experience (i.e., four to seven years after award of the doctorate) their proportions of Federal support looked similar to those of the workforce as a whole. However, except for psychology, they experienced a much sharper decline in Federal support between 1989 and 1999. (See appendix tables 5-38 and 5-39 and text table 5-14.)

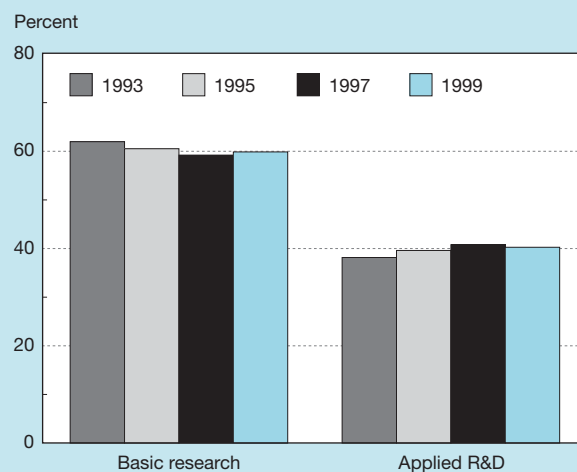
Has Academic R&D Shifted Toward More Applied Work?

Emphasis on exploiting the intellectual property that results from the conduct of academic research is growing. See “Outputs of Scientific and Engineering Research: Articles and Patents.” Among the criticisms raised against this development is that it distorts the nature of academic research by focusing it away from unfettered basic research and toward the pursuit of more utilitarian, problem-oriented questions. One aspect of this issue is addressed in this section.

Did a shift toward applied research, design, and development occur during the 1990s, a period when academic patenting and licensing activities grew steeply? Doctoral academic scientists and engineers were asked about their primary or secondary work activities, including four R&D functions: basic research, applied research, design, and development. These data are used to address the question posed here.

As figure 5-31 shows, a very modest shift away from basic research from 61.9 percent in 1993 to 59.9 in 1999, which barely reaches statistical significance, is evident among those listing research as their primary work activity. However, when the headcount of all researchers is considered, no such effect is seen. These data suggest that among those whose primary work activity is research, some modest shift toward more applied work may have occurred. They also suggest that most academic researchers do not perceive a shift toward more applied kinds of research functions.

Figure 5-31.
Distribution of academic researchers' activities, by research function



NOTE: Academic researchers include those whose primary or secondary work activity is basic or applied research, development, or design.

SOURCE: National Science Foundation, Division of Science Resources Statistics. Survey of Doctorate Recipients.

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Text table 5-14.

Percentage of academic doctoral scientists and engineers four to seven years after receiving their Ph.D. who have Federal support

Field	1979	1989	1999
S&E total	43.0	57.8	47.4
Physical sciences	52.0	72.4	57.0
Mathematics	32.3	39.0	32.2
Computer sciences	—	70.8	56.6
Earth, atmospheric, and ocean sciences	49.6	81.2	65.3
Life sciences	57.3	71.9	57.2
Psychology	39.3	36.1	35.6
Social sciences	20.8	33.2	22.8
Engineering	55.1	70.8	55.5

— = estimate suppressed because of small sample size

SOURCE: National Science Foundation, Division of Science Resources Statistics (NSF/SRS), Survey of Doctorate Recipients.

See appendix tables 5-38 and 5-39.

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